Ten years of SeaWinds QuikScat for circumpolar snow monitoring

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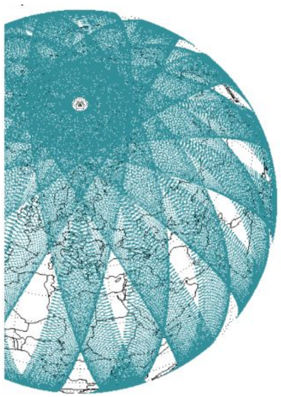
Seawinds on QuikScat

- Originally on QuikScat and ADEOS2
- Scatterometer – non imaging radar
- Band width is Ku-band (~13.4 GHz, 2.5 cm wavelength)
- this type of sensors is designed for ocean applications and the
- Swath 1800 km
- Short revisit intervals
- Availability: June 1999 – November 2009
- incidence angles of 46° for the inner beam, and 54° for the outer beam, with horizontal and vertical polarizations respectively, using a scanning dish antenna
- elliptical footprint size of roughly 24 km x 31 km at inner beam
- Distributed by JPL
- Predecessor: NSCAT on board ADEOS
  - Was only in operation for a few months 1996/96
  - But winter period was cover and the first snow analyses has been performed

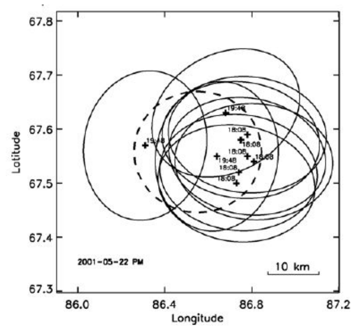


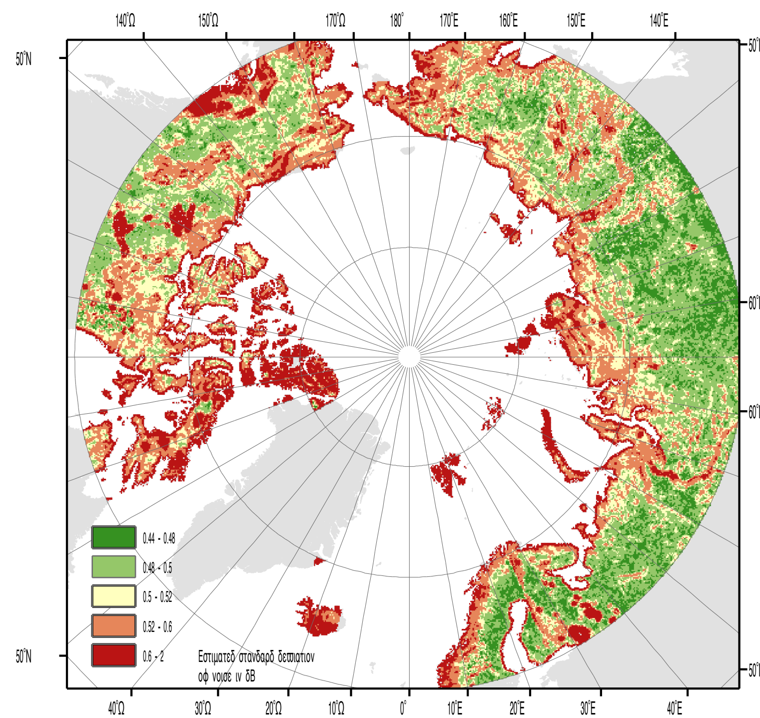
Daily coverage

Seawinds on QuikScat

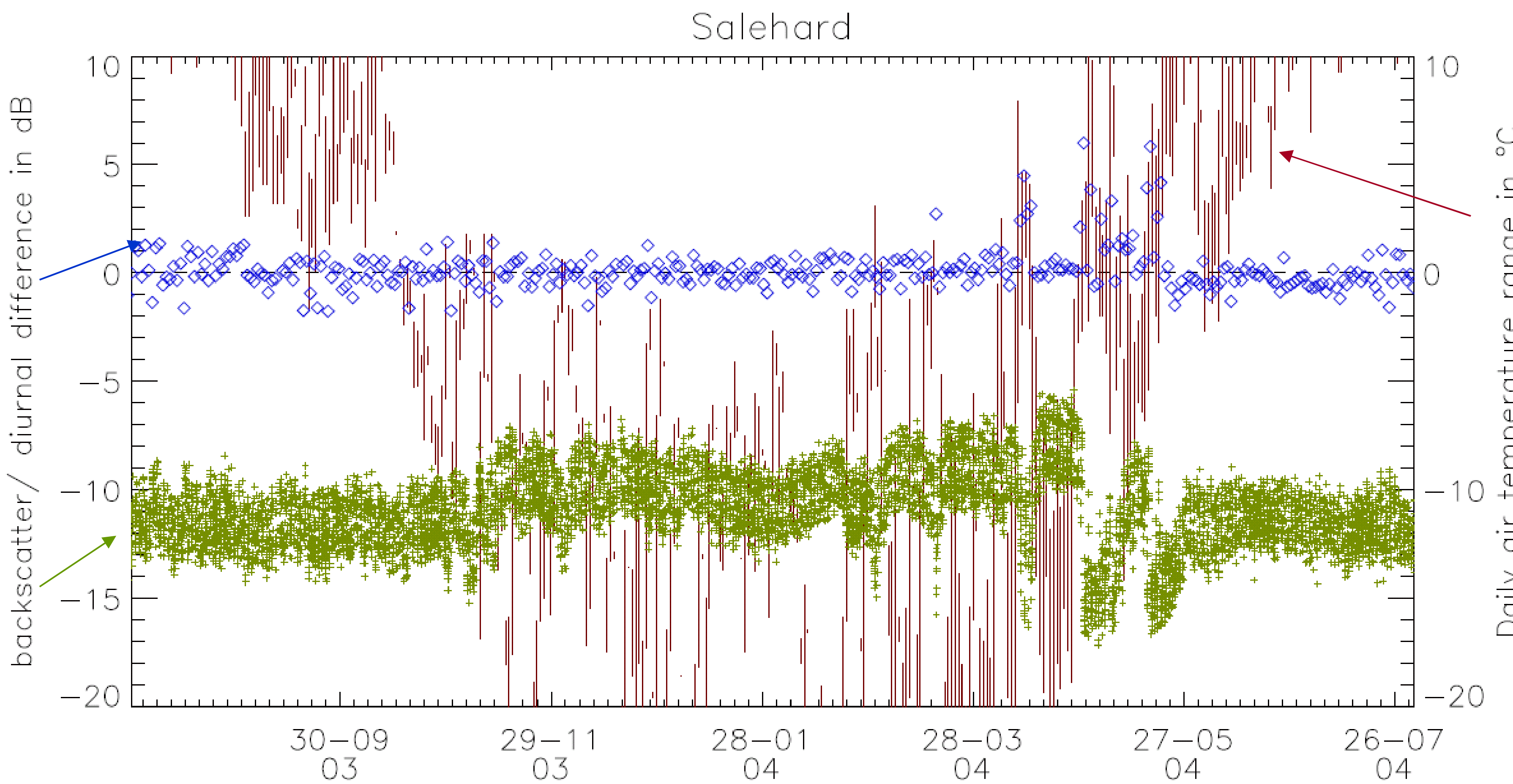
- Backscatter behaviour over snow
  - Depends on snow structure and depth
  - Increases due to
    - Snow depth increases
    - Metamorphoses of snow crystals – thaw and refreeze
  - Decreases when surface is melting
- Data need to be regridded (processing chains developed at BYU and TU Wien)
- Exhibits strong noise
- Snow application:
  - Seasonal snow melt detection
  - Melt season length on ice caps
  - Autumn freeze/up
  - Seasonal snowmelt duration
  - Ice crust detection

Example of footprint from a 12 hour period which are resampled to one specific grid cell





Seawinds on QuikScat

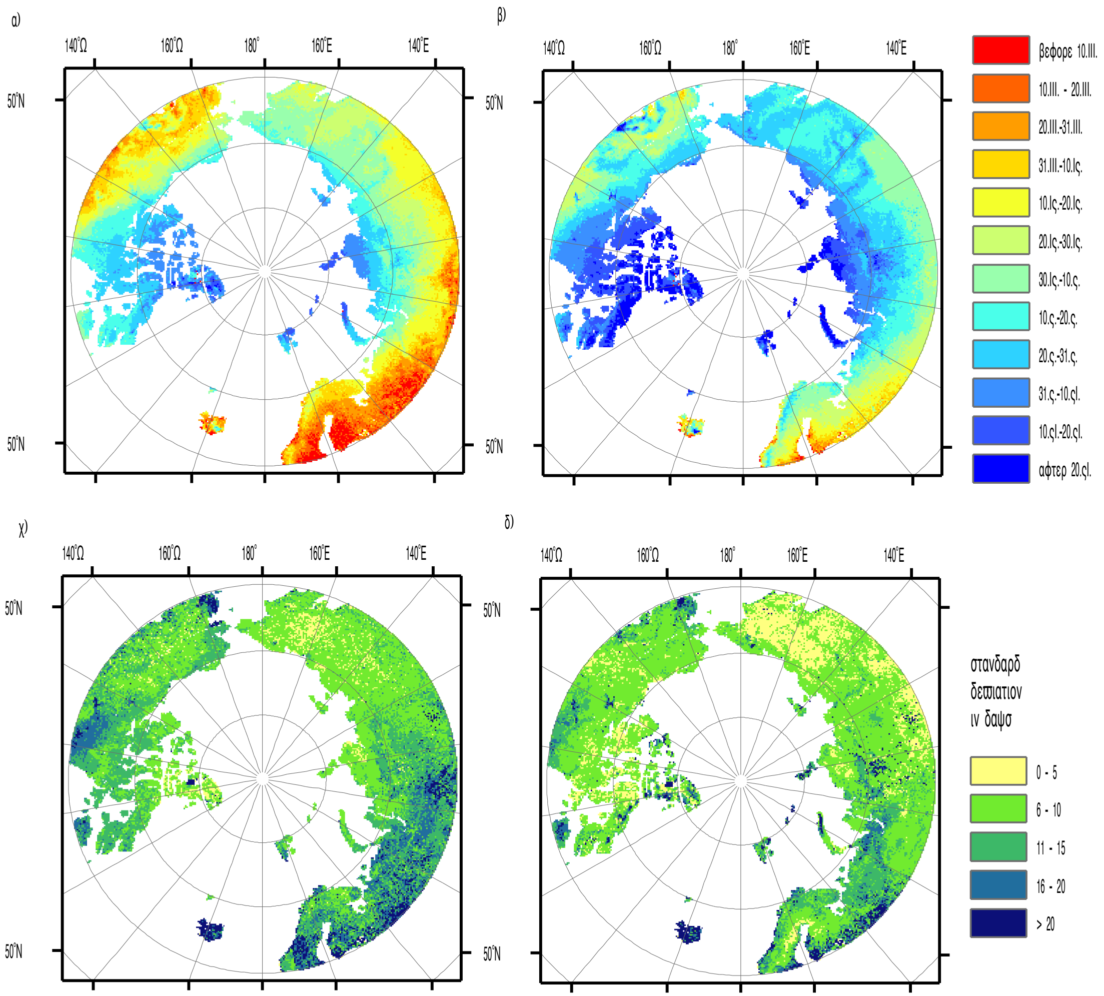


Seasonal snowmelt from scatterometer

Reference	Sensor	Method	Parameters
Boehnke & Wismann 1996	ERS (C-Band)	Location specific summer (July) and winter (February) backscatter	Thaw timing
Frolking et al. 1999	NSCAT	Five day average backscatter and location specific difference from overall mean	Thaw timing
Kimball et al. 2001	NSCAT	Application of similar method as in Boehnke et al. 1996	Thaw timing
Kidd et al. 2003, Bartsch et al. 2007	SeaWinds QuikSCAT	Diurnal differences with respect to noise and multiple thaw periods	Start and end of major thaw period
Kimball et al. 2004a	NSCAT	Extension of Frolking et al. 1999	Start, end, primary thaw date
Kimball et al. 2004b	SeaWinds QuikSCAT	As in Kimball et al. 2004a	Start, end, primary thaw date plus autumn refreeze
Brown et al. 2007	SeaWinds QuikSCAT	Fixed threshold for deviation from winter (February) backscatter level	Thaw timing
Wang et al. 2008	SeaWinds QuikSCAT	Application of method from Frolking et al. 1999 to average evening backscatter with respect to summer mean values (August)	Snow-off date

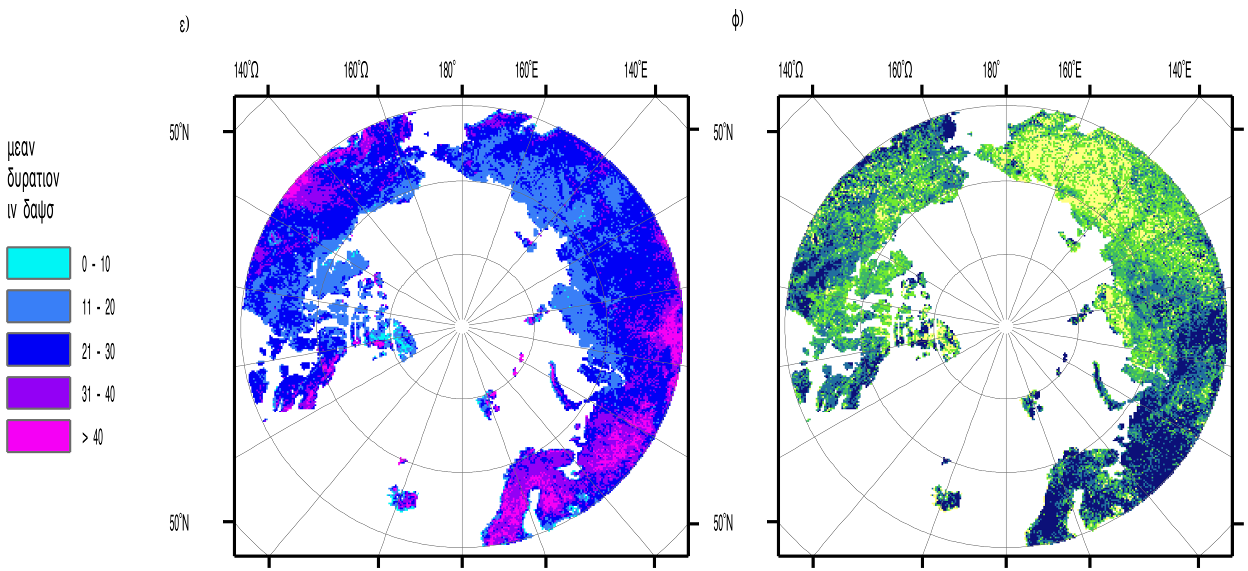
Seasonal snowmelt 2000-2009

start



end

Seasonal snowmelt 2000-2009



Ice crusts on snow

- Caused by snow surface thawing and refreezing due to
  - Rain on snow – ROS
  - General warming and subsequent cooling

- ROS are related to larger scale weather patterns, such as variations in the North Atlantic Oscillation (NAO) and the Pacific-North America pressure patterns (Rennert et al. 2009)
- Occurrence on regional to circumpolar scale is estimated by use of field data, re-analyses data and global climate models

- Decrease of duration of ice crust on top of snow cover in the Russian Arctic since 1980s (from snow course data)
  - Buligyna, O. & Groisman, P. 2009 (AGU)
- Mid winter ROS events may increase in
  - north western North America and European Russia (Rennert et al. 2009)
  - European Russia (Ye et al. 2008)

Impacts on wildlife

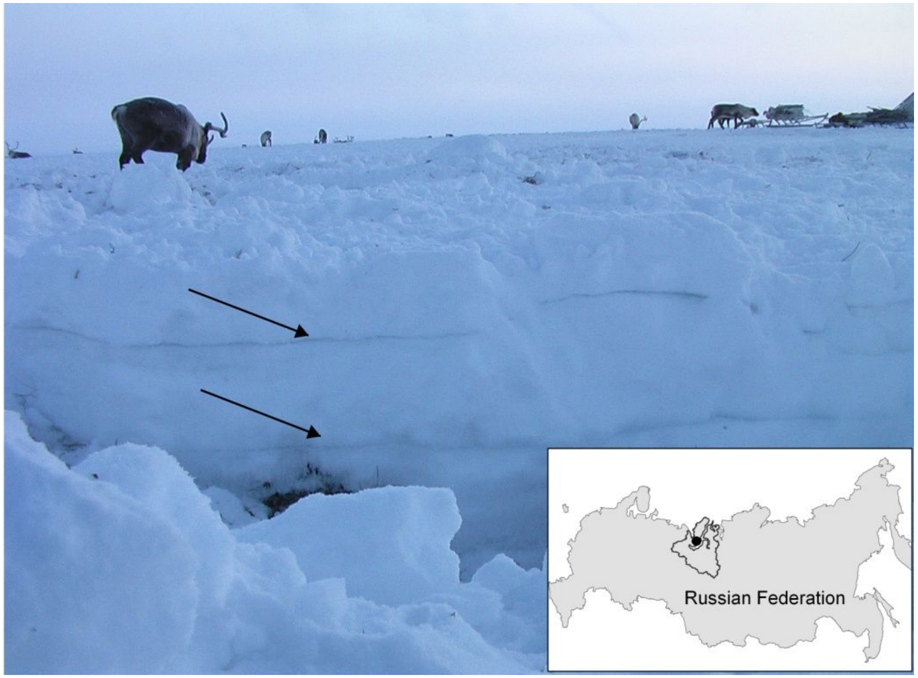
- ROS events are linked with large-scale ungulate deaths
  - reindeer, caribou, elk, musk-ox

- Example: Reindeer
  - Reindeer lichens are a main source of fodder during the winter and are dug up from beneath the snow when it is present.
  - The accessibility of terricolous lichens is therefore in large parts determined by snow properties.
  - Important parameters are the establishment of snow cover in autumn, snow depth, melting of snow in spring and the structure within the snowpack.
  - The refreezing of snow cover is used for modelling the vulnerability of reindeer husbandry to global change (Rees et al. 2008)

  - Bartsch, A., Kumpula, T., Forbes, B., Stammler, F. (2010): Detection of snow surface thawing and refreezing in the Eurasian Arctic using QuikSCAT: implications for reindeer herding. Ecological Applications e-View. doi: 10.1890/09-1927

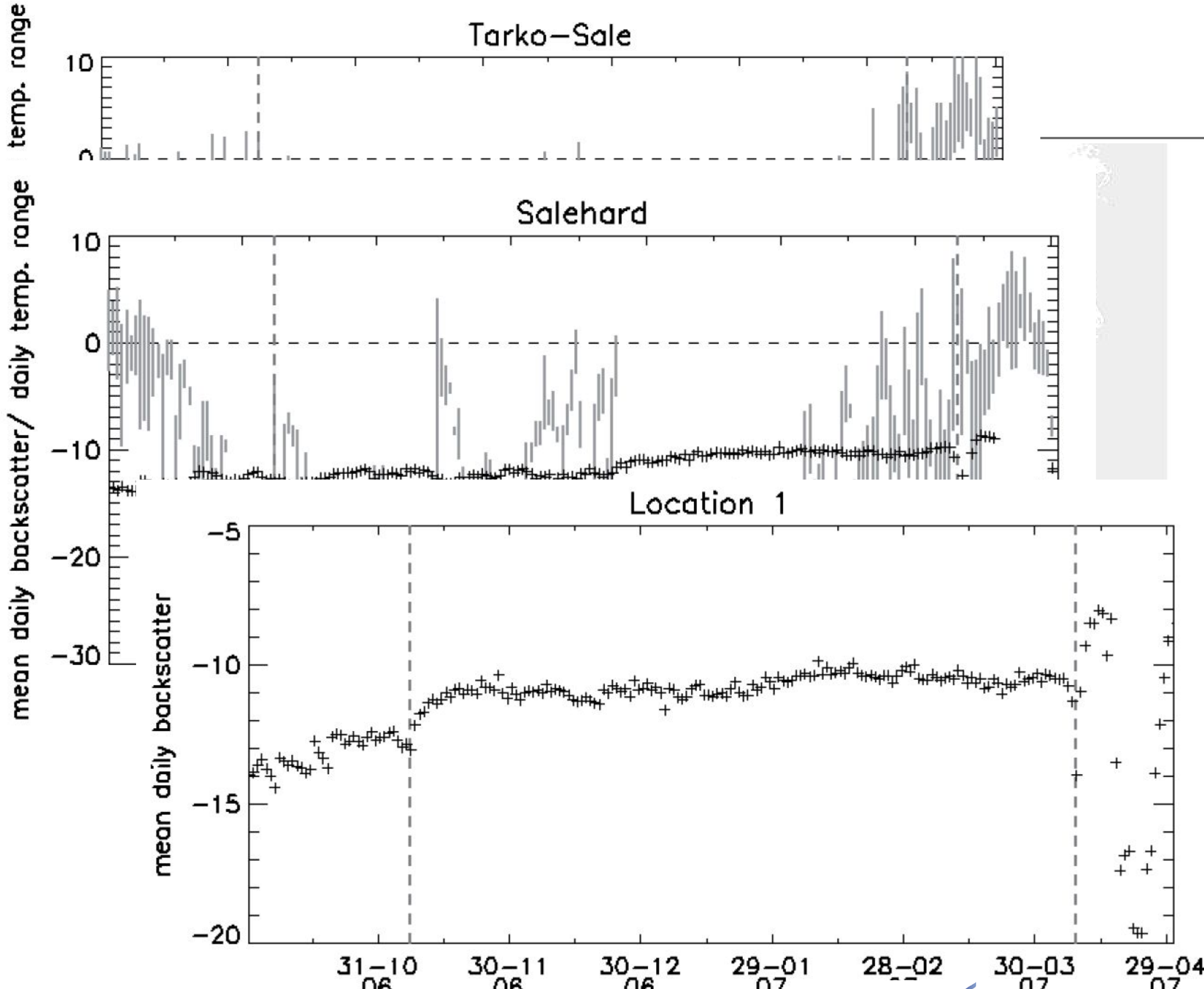
Implications for reindeer herding

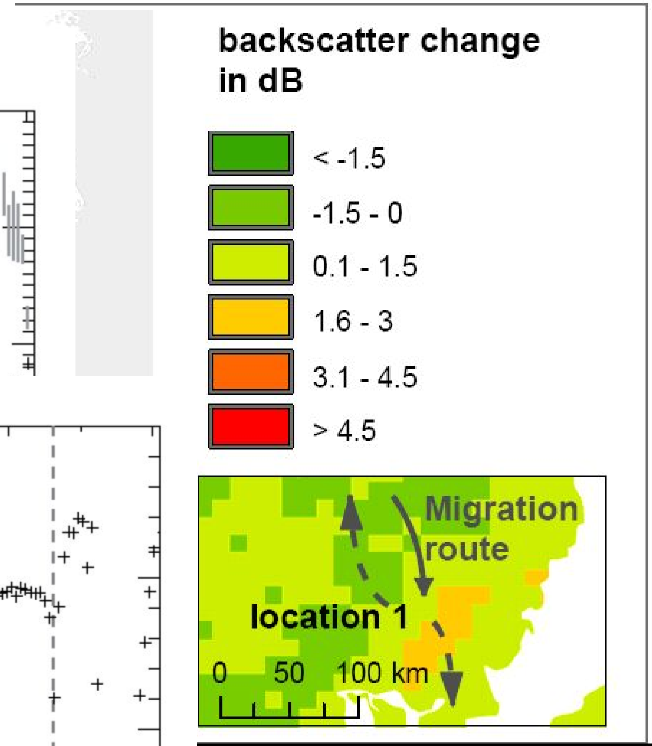
- Southern Yamal peninsula has been affected by a rain-on-snow (ROS) event in November 2006.
- The ROS event and subsequent refreezing with formation of ice crusts **forced a major change in migration**.
- Some of the brigades were additionally affected by an event to the west in January and as they migrated back northwards across the snowpack, which still consisted of the previous ice layers. **The loss amounted to 25% of the animals including deaths and still-births resulting from exhaustion and poor nutrition of pregnant females.**



Snow profile taken on the 19th of November 2006. (Photo: Florian Stammler)

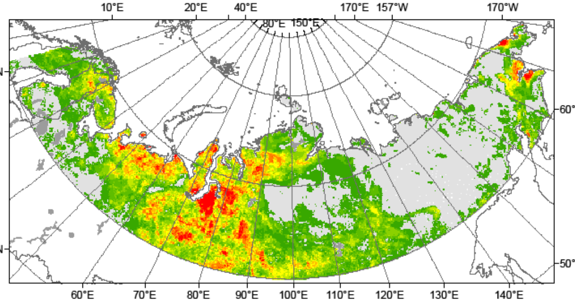
The Yamal event



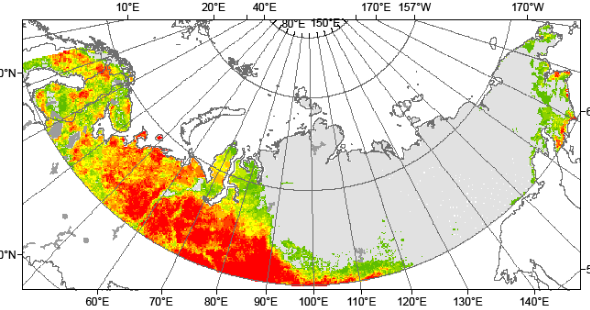


Results – Northern Eurasia 2000-2009

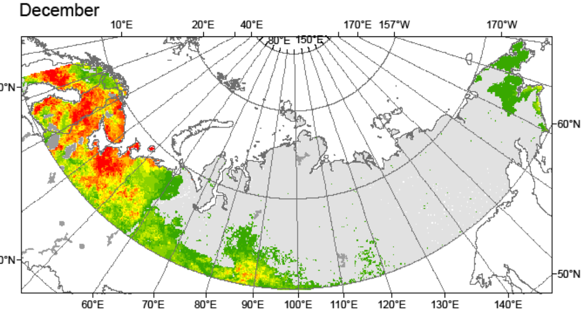
October



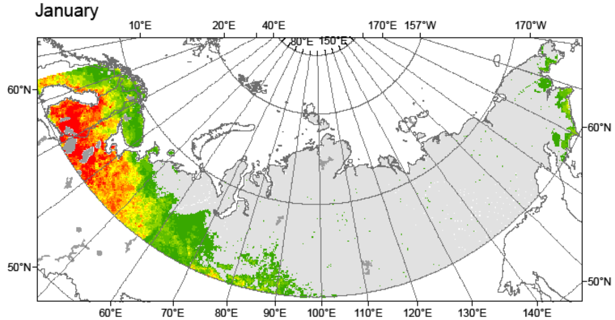
November



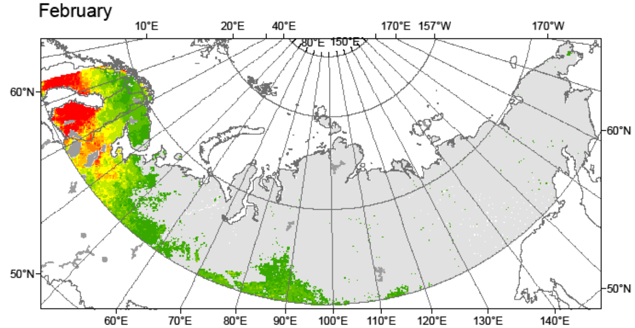
December



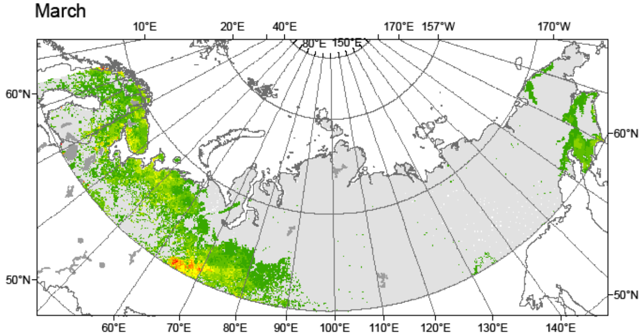
January



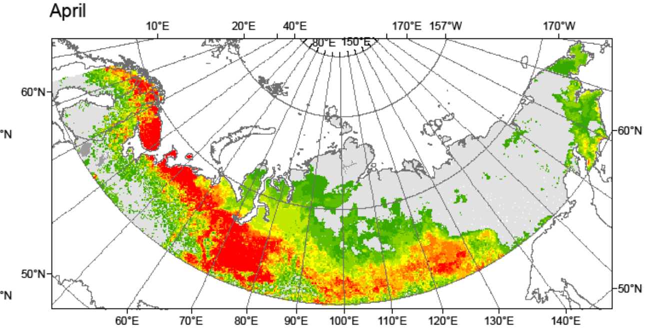
February



March



April



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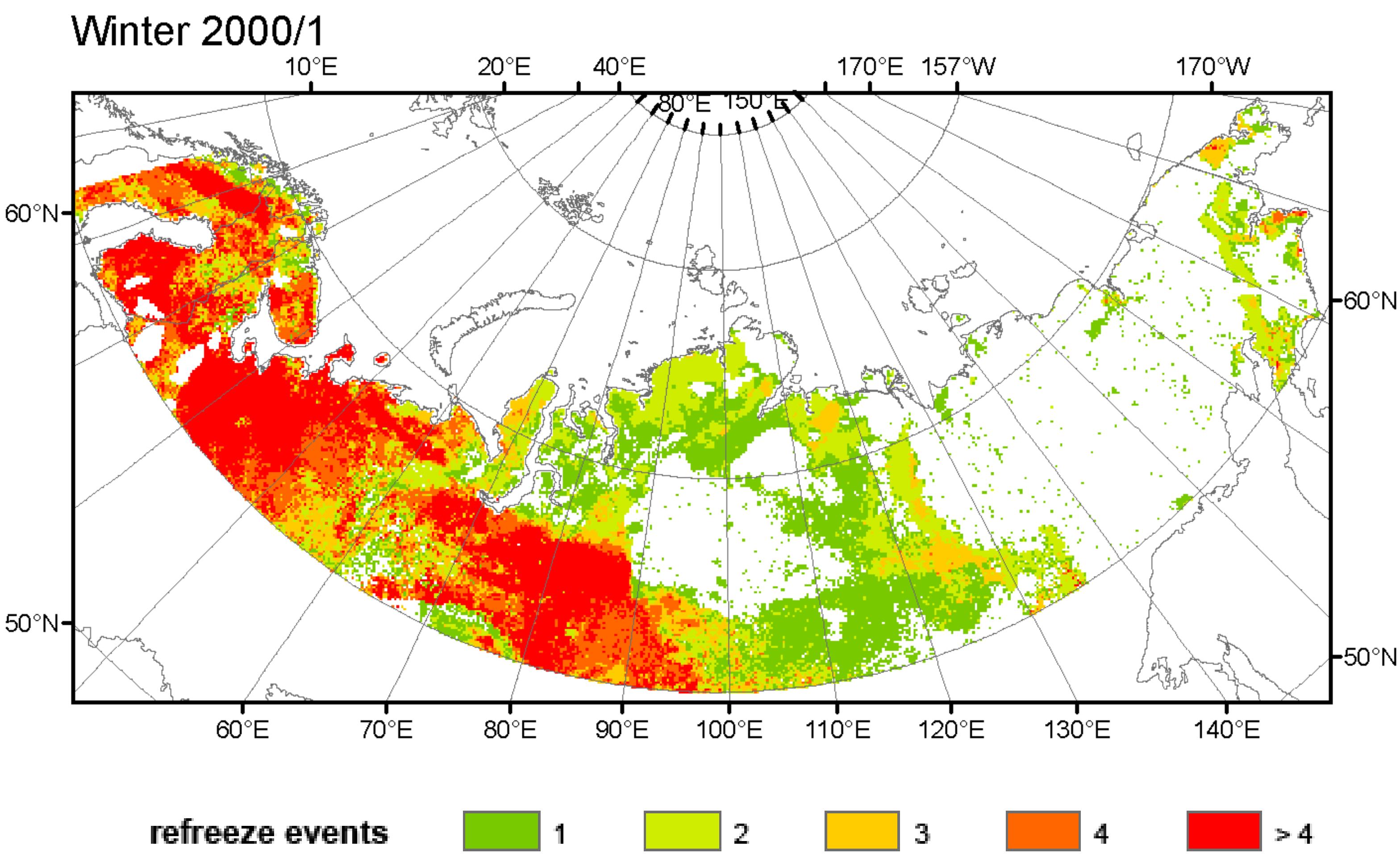
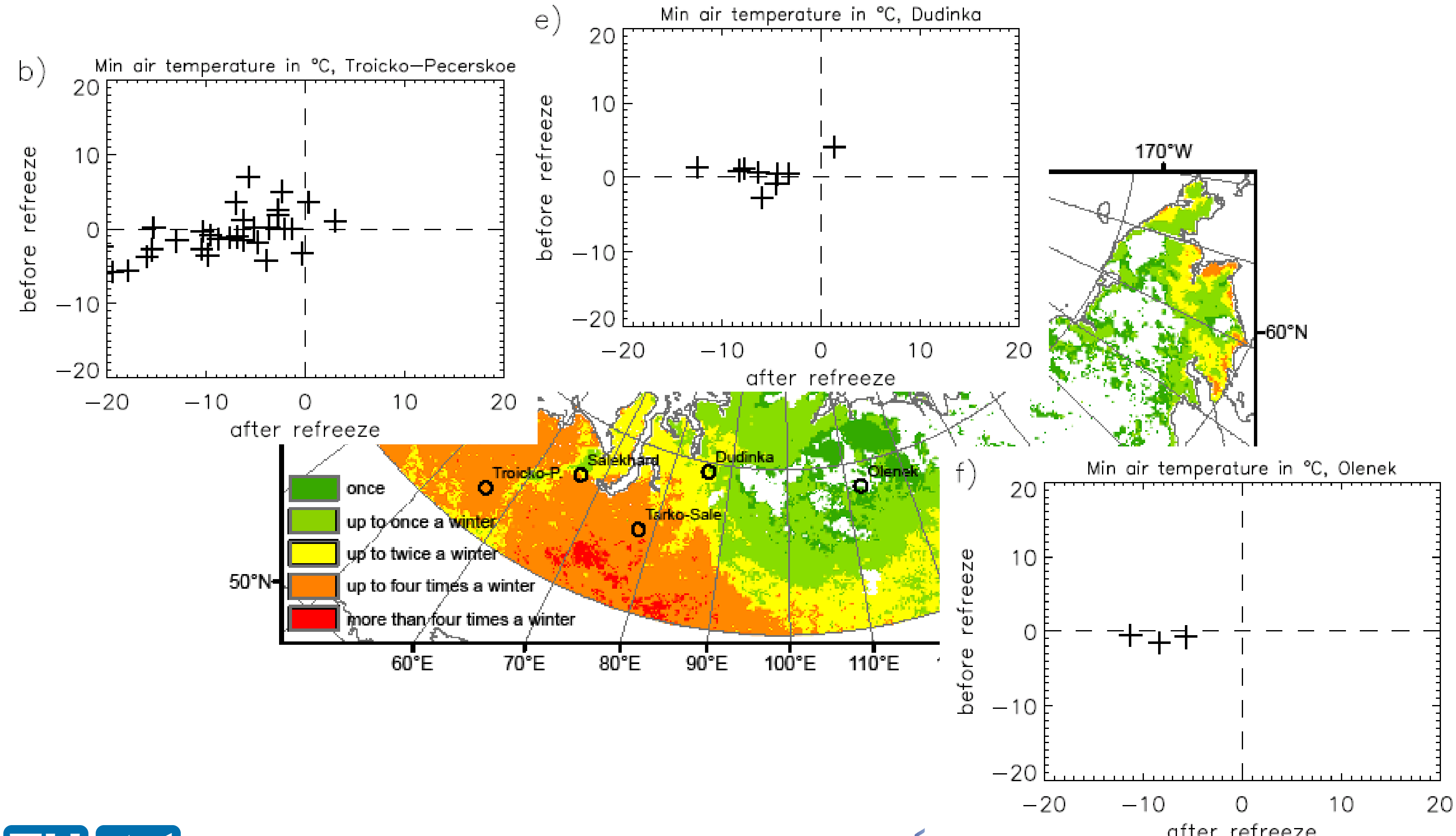
Results – Northern Eurasia



Results – Northern Eurasia

- Comparison with WMO station data



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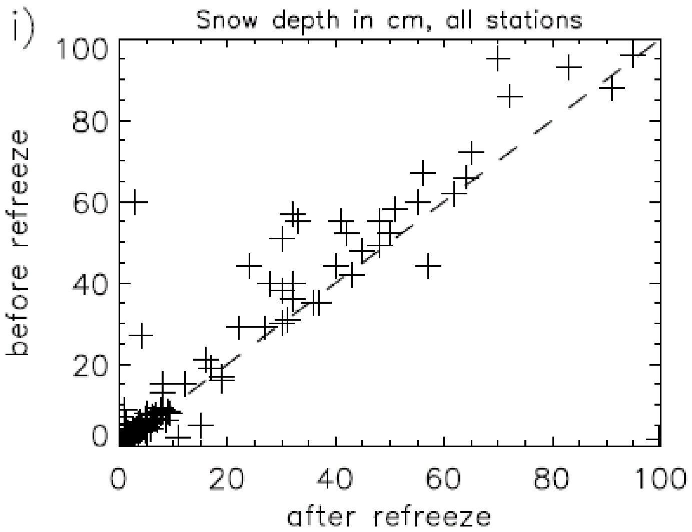
Discussion Northern Eurasia I

- Captured events do relate to cooling events
- Backscatter increase also does not relate to heavy snowfall

- But
  - it needs to be determined whether all events are captured
  - It cannot be distinguished if the snow structure change is due to rain –on-snow
  - Does not reveal severity of events

- Results agree with other data sources



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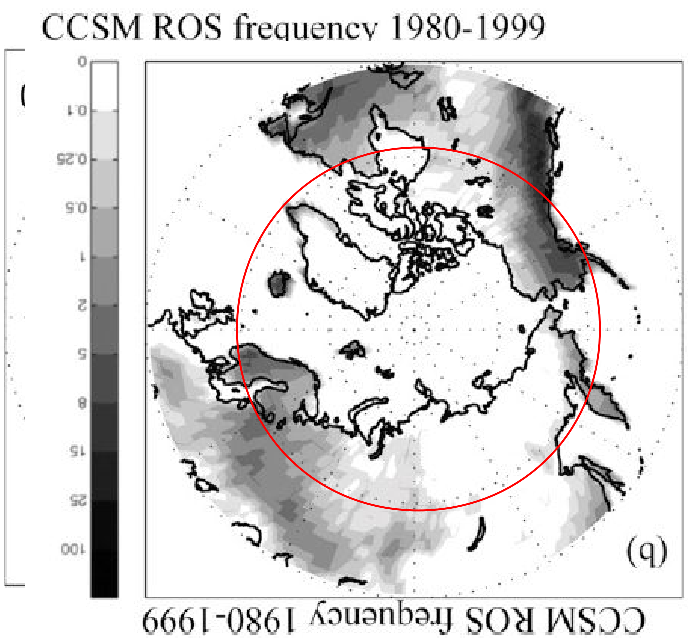
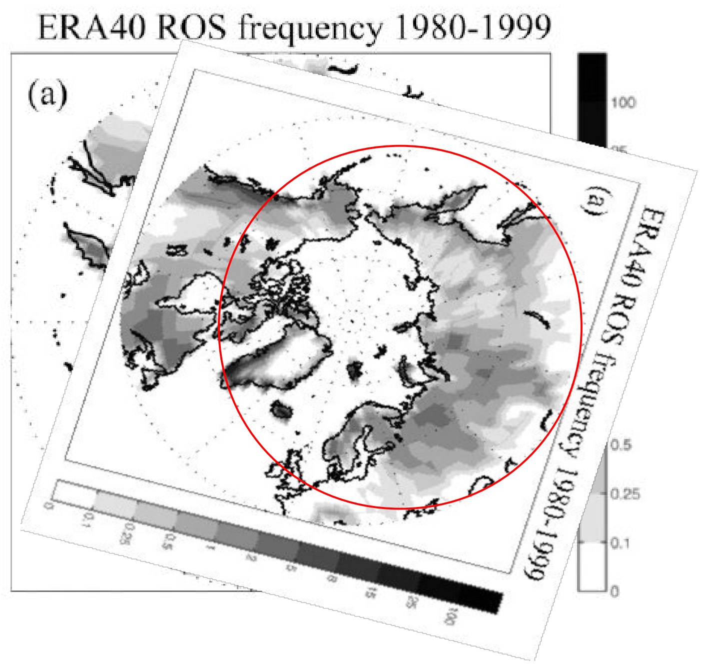
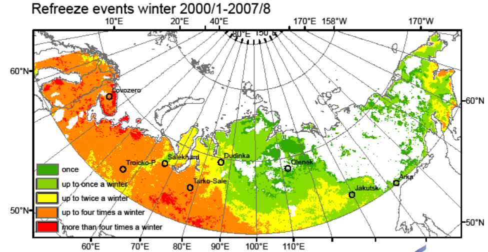
Comparison with other data sources

Rennert et al. 2009







Discussion Northern Eurasia II

- Severity for reindeer herding
  - Thresholds used have been determined based on in the field determined sever events
  - Any ice crust, independent whether its from ROS or not is problematic
  - Timing of events is crucial
    - early winter
    - spring

- Footprint size roughly 24 km×31 km! - Heterogeneity

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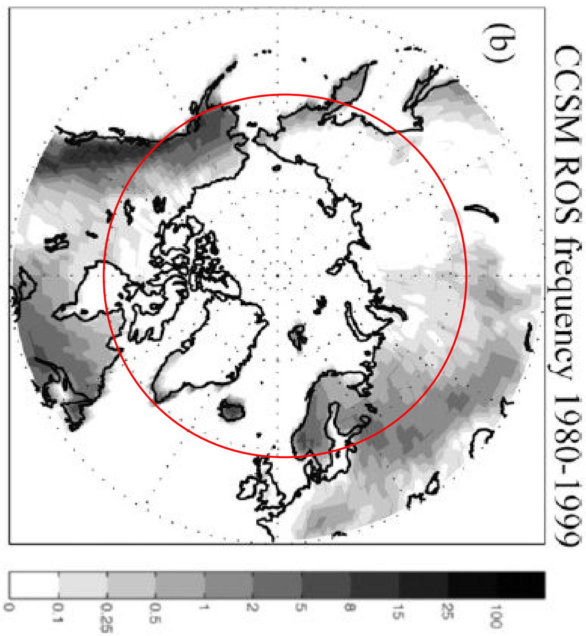
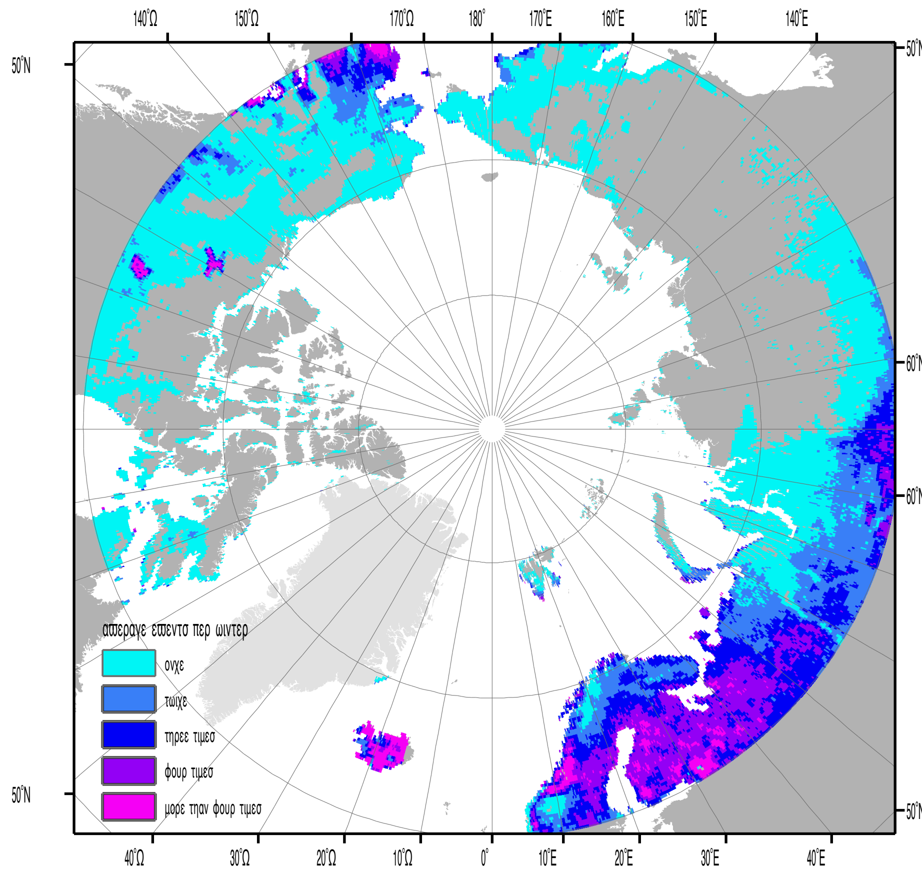
Circumpolar

- Midwinter
- November to February
- 2000 - 2009



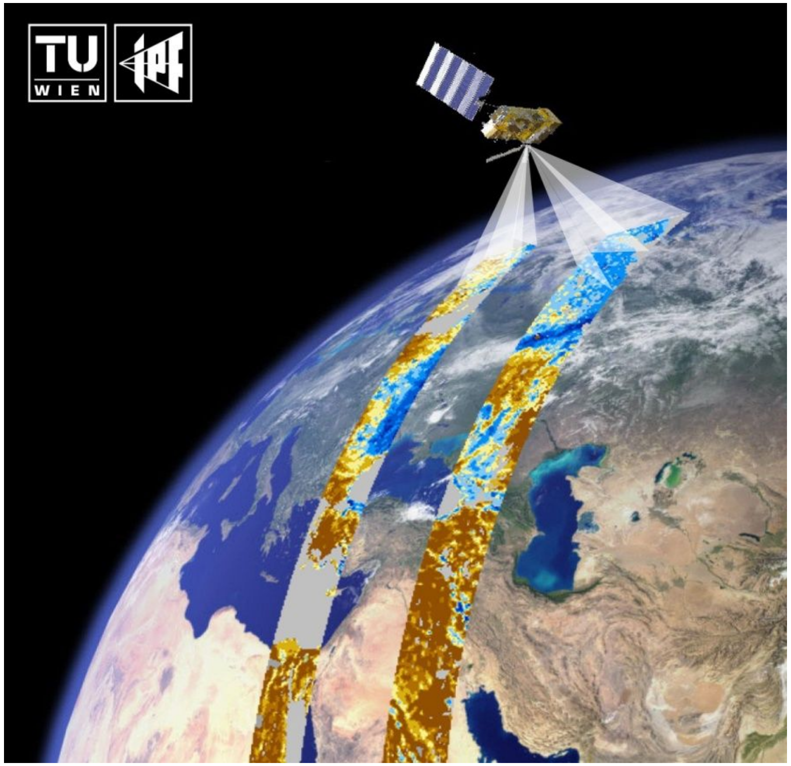
Renne et al. 2009



Bartsch (2010)

Outlook I

- Comparison with field (snow course) data of ice crusts
- Transfer to other sensors for continuation of records – **trend analyses!**
  - Currently operational scatterometer with daily measurements is Metop ASCAT
  - Its continuity is ensures since it is part of a series of satellites used for weather forecasting by EUMETSAT
  - But it operates at a longer wavelength (C-band) and is less sensitive to changes of snow properties



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Outlook II

- Ku-band and also X-band have been identified as most suitable for snow applications and are considered for possible future SAR satellite missions which are dedicated to snow monitoring (ESA CoReH2O)
- A Ku-band scatterometer for the purpose of ocean wind detection is also aboard Oceansat II (launched by the Indian Space Research Organisation on September 23, 2009)
- A similar Ku-band sensor which will additionally acquire in C-band (Dual Frequency Scatterometer: DFS) is in preparation by the National Oceanic and Atmospheric Administration (NOAA) in cooperation with the Jet Propulsion Laboratory (JPL) and the Japan Aerospace Exploration Agency (JAXA) for launch in 2016 as part of the Global Climate Observation Mission-W2

- Bartsch, A. (2010): Ten Years of SeaWinds on QuikSCAT for Snow Applications Remote Sens. 2010, 2(4), 1142-1156; doi:10.3390/rs2041142